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# **NASA Corrosion Engineering Laboratory**

## **J. F. Kennedy Space Center, Florida, USA**

**NASA Engineering Directorate**  
**Laboratories, Development, and Testing Division**  
**Materials Science Branch**

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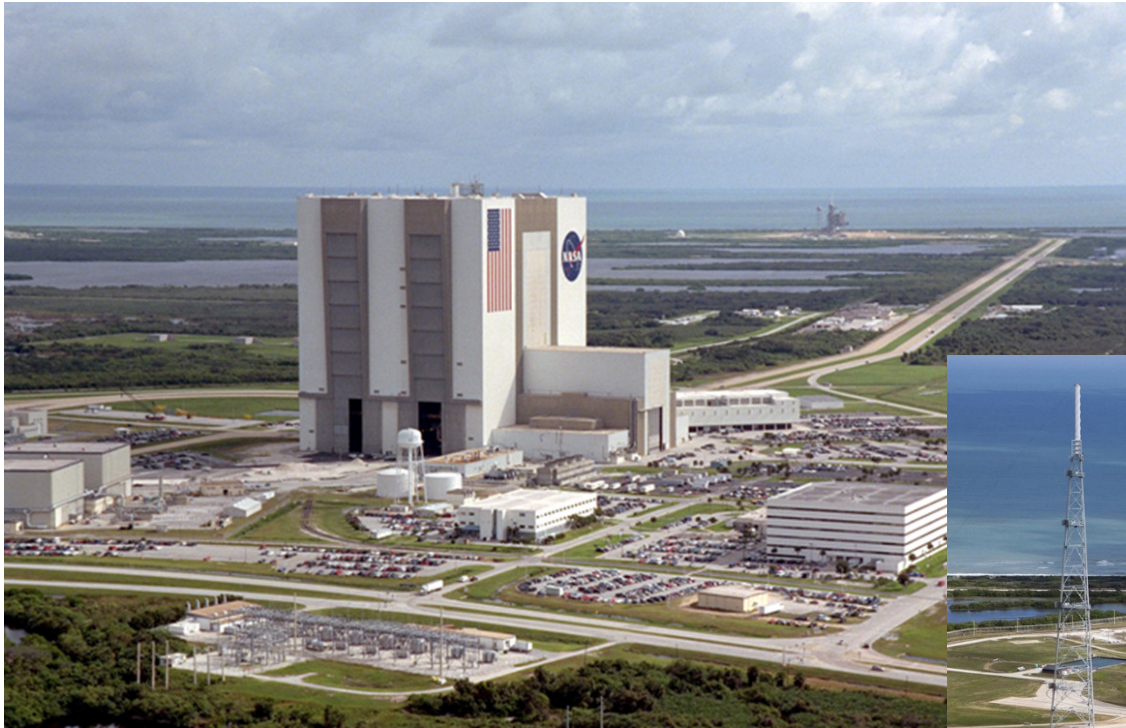
# Outline

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# KSC Launch Environment



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Positioned within 1,000 ft (305 m) of the Atlantic Ocean, KSC's launch facilities are exposed to salty air that blows from the ocean, high ambient air temperatures, and an extensive amount of UV Light. The high temperature of heavy lift engine exhaust is up to nearly 5,000°F (2,760°C). Close to 70 tons of 0.1M hydrochloric acid (HCl) are generated by the combustion products of a rocket's solid propellant. Corrosive conditions are prevalent at KSC.

# **NASA Corrosion Engineering Laboratory Missions**

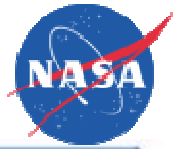
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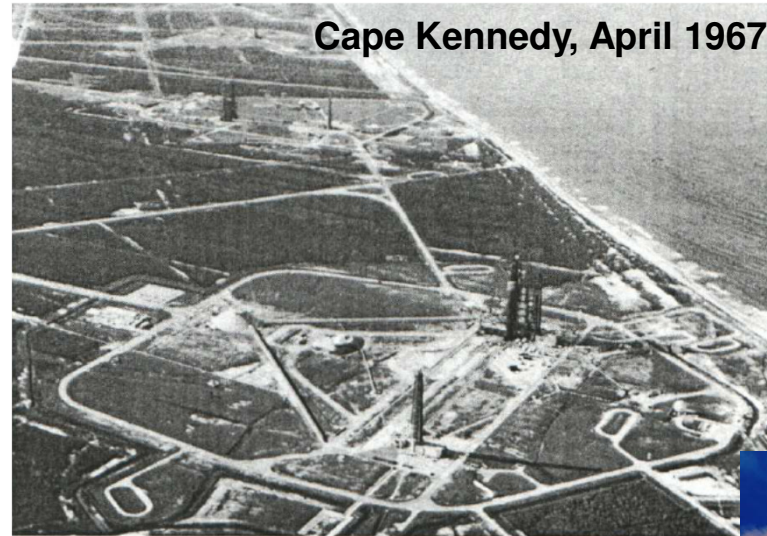
- **Conducts applied research and corrosion testing.**
- **Investigates, evaluates, and determines materials performance and degradation in different environments in support of NASA, other government organizations, industry, and educational institutions.**
- **Provides consulting and testing services.**
- **Represents NASA at the DoD Corrosion Forum and the Specifications, Standards, and Qualification Process WIPT.**
- **Participates in educational outreach activities.**
- **Maintains Beachside Atmospheric Corrosion Test Site:**
  - **Documented by ASM as one of the most corrosive naturally occurring environments.**
  - **Actively maintained for 48 years.**
  - **Historical database for evaluation of new materials.**



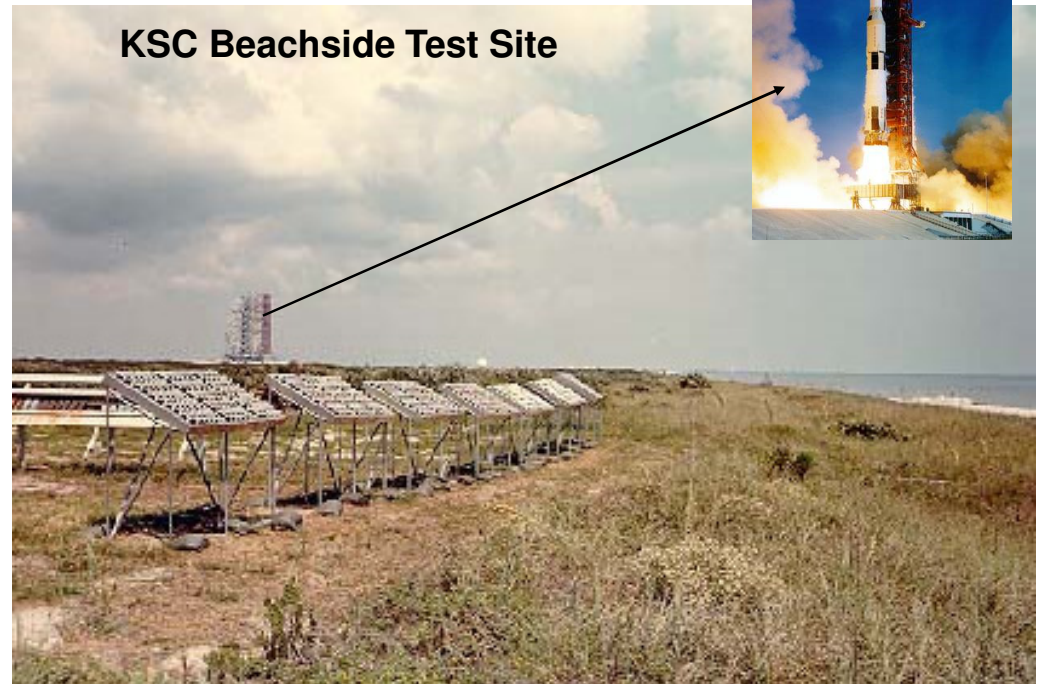
# Corrosion Laboratory/Atmospheric Exposure Test Site History



- **1962:** The Kennedy Space Center (KSC) begins operating as NASA's launch center for both manned and unmanned missions. The naturally corrosive marine environment causes many corrosion failures.
- **1966:** First atmospheric exposure testing of coatings for corrosion protection of carbon steel begins near the Cape Kennedy launch pads during the Gemini/Apollo Programs.
- **1969:** The NASA Beachside Corrosion Test Site established more controlled and cost effective ways to conduct testing on coatings for carbon steel in a seacoast launch environment.



Cape Kennedy, April 1967

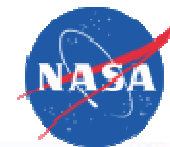


KSC Beachside Test Site

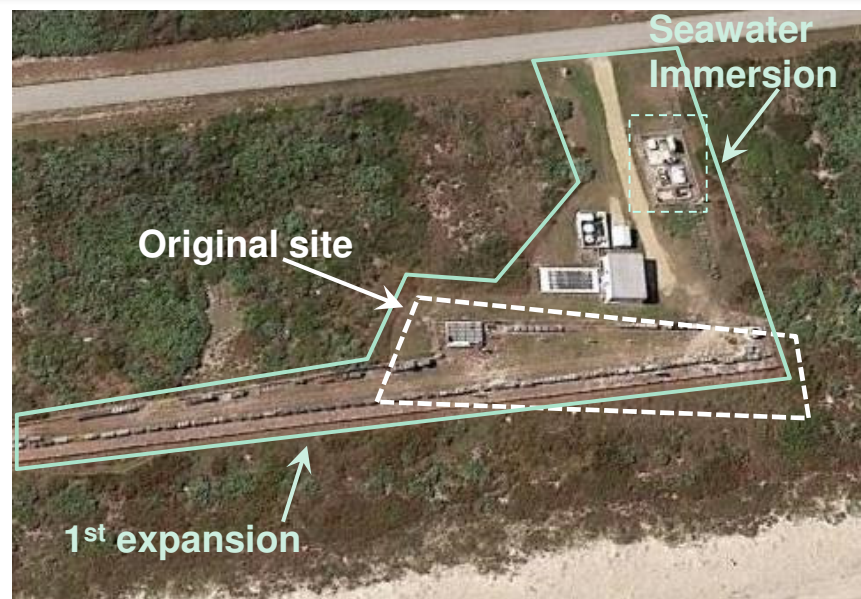


Saturn V

# Atmospheric Exposure Test Site History



- **1990's:** Numerous studies at the site required an expansion to 600 feet parallel to the Atlantic Ocean
- Environmentally friendlier coatings, zinc-rich primers and inorganic topcoats, silicone ablative coatings
- Identified materials, coatings, and maintenance procedures for launch hardware and equipment exposed to the highly corrosive environment at the launch pad
- **2000's:** Site upgraded to include a weather station, permanent building with laboratory and machine shop, remote camera system, remote field monitoring, seawater immersion and spray tanks.
- **2014:** Site expansion as a result of current demand for additional corrosion testing from NASA, the Department of Defense and other external customers
- 900 total feet of coastal atmospheric exposure space parallel to the Atlantic Ocean





# Capabilities: Atmospheric Exposure Test Sites



- Eight total atmospheric test sites across KSC.
- Main site is the Beachside Atmospheric Corrosion Test Site, which is a qualification site for various standards and tests products for NASA, DoD, other government entities, and industry.
- Six other sites measure corrosion rate (yearly covered and uncovered) and chloride concentration (monthly) as a function of time and distance from the Atlantic Ocean.
- Test site key:
  - 1) Beachside Atmospheric Test Site
  - 2) Launch Complex 39B perimeter
  - 3) 1.25 mile distance from the Atlantic Ocean along the crawler way
  - 4) 5 mile distance from the Atlantic Ocean along the NASA Causeway
  - 5) Ascent Wind Profiler site
  - 6) 16<sup>th</sup> floor of the VAB
  - 7) Launch Experimental Test Site within the KSC Industrial Area
  - 8) Outside near the VAB/LCC area



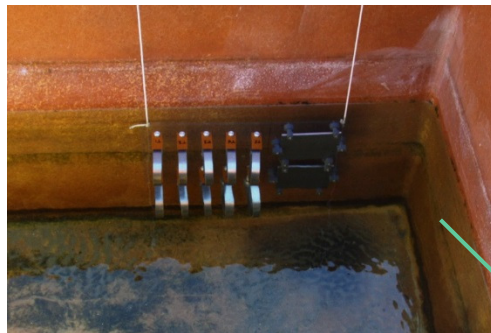
# Capabilities: Beachside Atmospheric Exposure Test Site



- 900 linear feet of beach front corrosion space along the Atlantic Ocean.
- Accommodates small test panels and a variety of other odd shapes and sized components for fully exposed and partially covered exposures.
- On-site laboratory and machine shop.
- Seawater flow tanks with full/alternating immersion and seawater spray capabilities.
- Full weather station and remote cameras.
- Corrosion rate and chloride concentration measured seasonally.

## Seawater immersion:

- Simulates natural tidal conditions
- Water Quality (pH, dissolved oxygen, chlorides, temperature)  
Oxygen concentration monitored



## Alternating Seawater Spray Test:

- Sprays seawater pumped from the ocean
- Frequency programmable





# Capabilities: Accelerated Corrosion Methods



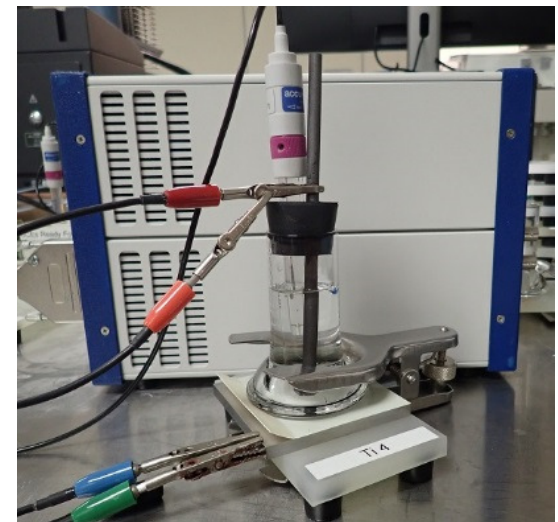
- Two salt fog and three UV chambers, as well as a humidity chamber, are available for accelerated corrosion and other materials testing
- NASA KSC has the equipment and experience to conduct electrochemical testing using a variety of both AC and DC methods. NASA typically uses this equipment for evaluating coatings at distinct points during atmospheric exposure periods via electrochemical impedance spectroscopy (EIS), and determining materials compatibility of metals that will be immersed in unique aqueous solutions for the duration of their use via cyclic potentiodynamic polarization (CPP).



**UV Chamber**



**Cyclic Salt Fog Chamber**

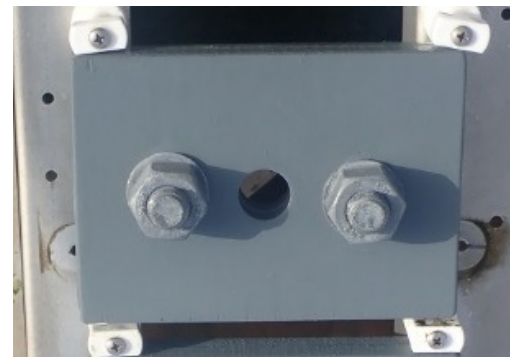


**Electrochemical Set-up**

# Capabilities: Coatings Application and Testing



- Ensures that coatings are applied in a prescribed and consistent manner to SSPC, NACE, and military specifications.
- A variety of common structural and aerospace-related metal samples for the most common testing. Common test articles: flat panels, panels with welded c-channels, fastener configurations, bolt, stress-corrosion cracking, and dissimilar metal configurations.
- Access to a large variety of machining and preparation facilities outside of the Corrosion Engineering Laboratory but still within the confines of NASA KSC for specialty needs
- Surface preparation including grit blasting and polishing. Laboratory and full production scale facilities for degreasing, etching, and passivating metals.
- Coatings application methods for both inorganic and organic-based coatings and Corrosion Preventive Compounds (CPCs) applied via brush or spraying methods, such as airless, gravity fed or pressure pot conventional, and HVLP. Laboratory and full production scale facilities for applying conversion coatings and other pretreatments.
- Prepare samples for testing such as scribing via hand scribing or with an auto-scriber tool.



# Capabilities: Physical and Chemical Testing

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- Corrosion testing is performed in tandem with mechanical and chemical testing based on the larger program needs.
- Coating testing: thickness, hardness, pull or peel strength adhesion, color, gloss, solar emissivity, reflectivity.
- Stress corrosion testing: Bent beam, U-bend, C-ring, and tensile type specimens in accelerated or long-term atmospheric test environments.
- Tensile testing: Fatigue, stress, compression, lap shear, adhesion.
- Chemical interface characteristics and degradation: FT-IR, SEM, XPS, and surface hydrophobicity via contact angle
- Non-Destructive Evaluation (NDE): CT scanning, X-ray, dye penetrant, ultrasound, and terahertz.
- Specialty Testing: Vibration, vacuum, electrostatic, electrical, conductivity.

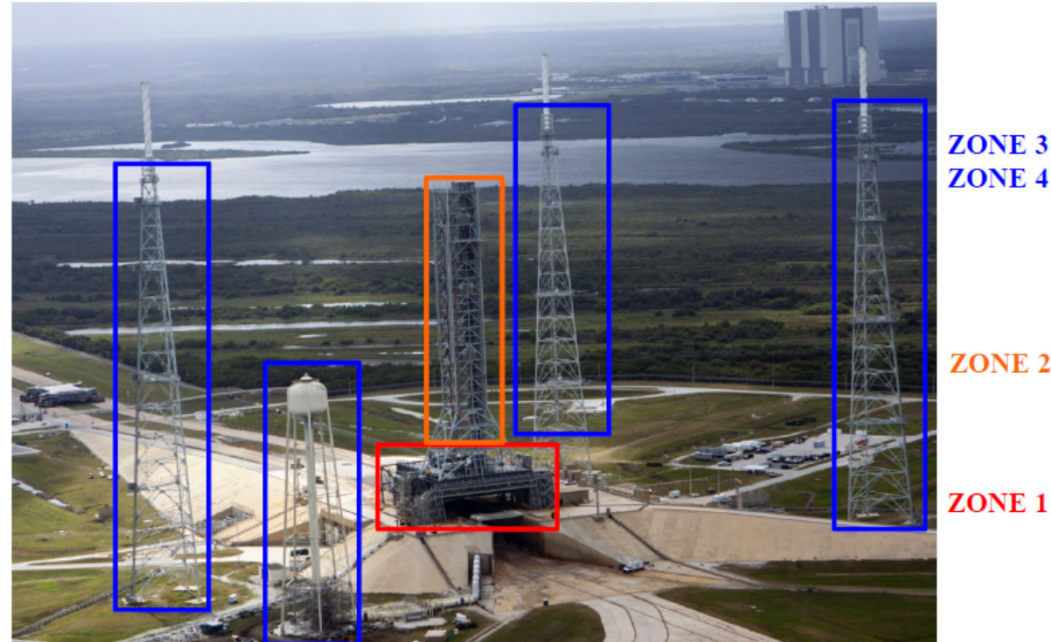


# Qualifying Coatings for use at NASA



## Specification NASA-STD-5008B: Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment

- Governs maintenance at John F. Kennedy Space Center and other NASA Centers.
- Establishes practices for the protective coating of ground support equipment and related facilities.
- Zones of Exposure are established to define coating system requirements for specific environments at, but not limited to, the heavy lift launch complex.



Heavy lift launch complex 39 zones of exposure



# Preparation of Test Panels

- **NASA prepares all panels for testing in-house to ensure consistent application between coating types and maintain objectivity.**
- **Standard AISI M1020 carbon steel test coupons**
  - Two types: flat panel with c-channel weld and flat panel
- **Surface cleanliness & roughness of coupons**
  - Inspected, measured, and documented before application of primer



Panel with C-channel Weld

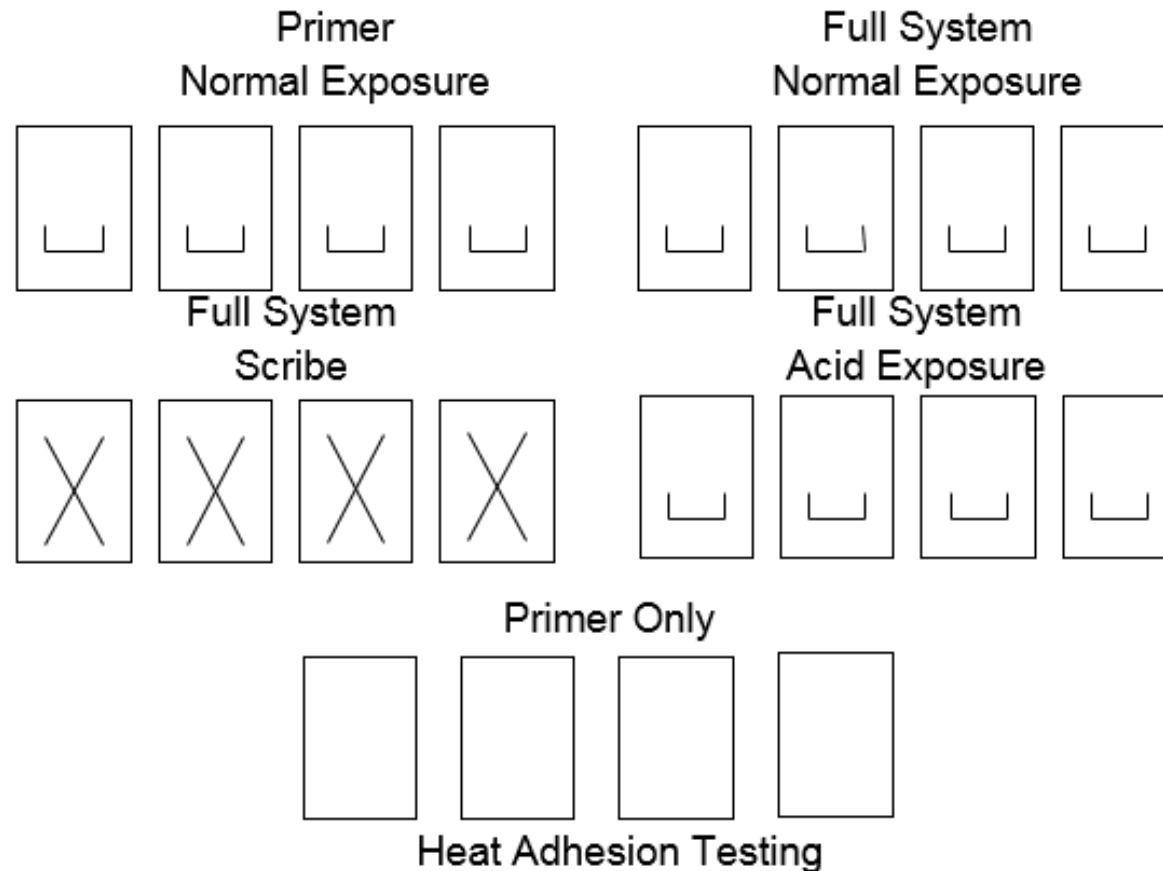


Flat Panel



# Test Matrix

- 4 composite primer only (normal conditions)
- 4 composite top coated (normal conditions)
- 4 composite top coated (acid conditions)
- 4 flat top coated (scribe test – normal conditions)
- 4 flat primer only (to measure heat resistance/adhesion)





# Coating Evaluation Protocol

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## Adhesion Testing

- Preheat and Post Heat (400C – 24 hours) are recorded.
- Post heat adhesion value must be greater than pre heat adhesion value, and meet the statistical requirements for repeatability.

## Atmospheric Exposure Testing

- Evaluations performed after 18 months of exposure for initial qualification.
- Final evaluations performed after 60 months of exposure for final approval and placement on the approved products list.
- Acidic slurry is placed on the appropriate panels every six weeks for the first 18 months of exposure.

## Photographs

- Taken prior to exposure, and after 18 months and 60 months of exposure.

## Color/Gloss (Not a pass/fail criteria)

- Color and gloss are taken prior to, and after 18 months of atmospheric exposure.

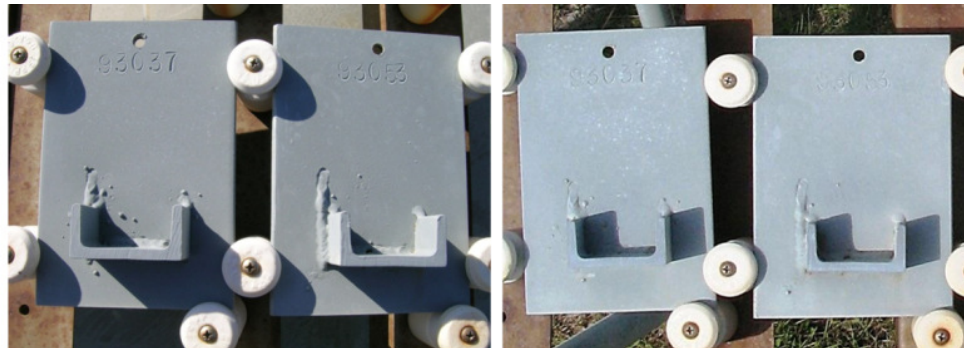
## Blistering, corrosion under paint, and corrosion from the scribe evaluations (Pass/fail criteria)

- Corrosion evaluations are performed after 18 months and 60 months of environmental exposure.

# Corrosion under Paint



- Corrosion under paint is a pass/fail Criteria.
- Acid rinsed and non acid rinsed are evaluated by this method.
- Corrosion Under Paint is determined via pictorial examples in ASTM D610, “Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surface”.
- According to NASA-STD-5008B, a rating of 8 (>0.03% to 0.1% rusted for aliphatic polyurethane, water reducible, and polysiloxane topcoats) or 9 (>0.01% to 0.03% rusted for inorganic zinc).



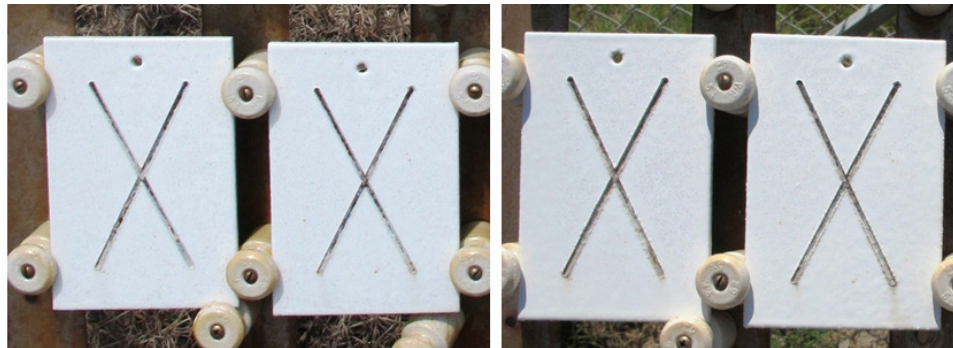
18 month and 60 month exposure – Approved for Use



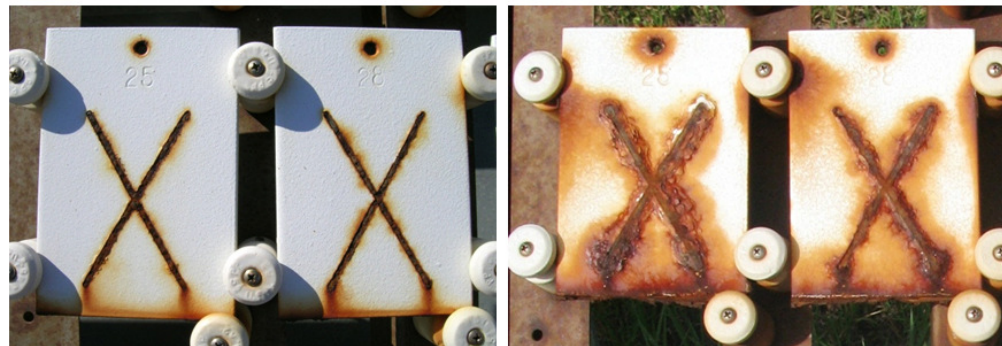
18 month and 60 month exposure – Not Approved for Use

# Corrosion from the Scribe

- Corrosion from the Scribe is a pass fail criteria.
- These panels are not acid rinsed.
- Corrosion from the Scribe is determined via measurements of creep from the scribed region according to ASTM D1654, “Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments”.
- According to NASA-STD-5008B, a rating of 8 (mean creep > 0.5 mm to 1.0 mm for aliphatic polyurethane, water reducible, and polysiloxane topcoats) or 9 (mean creep > 0.0 mm to 0.05 mm for inorganic zinc).



18 month and 60 month exposure – Approved for use



18 month and 60 month exposure – Not approved for use



# Use of Facilities for Non-NASA Needs

- NASA partners with Federal and state government agencies, U.S. businesses, and universities through agreements where each partner provides resources such as funding, facilities, or expertise, to achieve a common goal. As a result of work being done at KSC, patents are available for licensing.
- NASA's unique corrosion facilities and expertise are available to the private sector on a reimbursable basis. If you would like to contact us about materials research or testing opportunities, we would be happy to answer any questions you might have.
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